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AIR WEATHER SERVICE

NCAR SONDE
FLIGHT TEST REPORT

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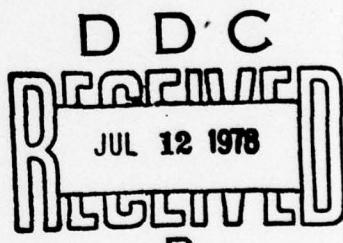
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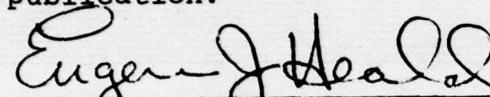
EUGENE J. HEALD, Maj, USAF
Director, Airborne Sys Eng
DCS/Logistics

FOR THE COMMANDER

PAUL F. PULSE II, Lt Col, USAF
DCS/Logistics

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report documents an operational test of the National Center for Atmospheric Research (NCAR) wind-finding dropsonde. The testing, conducted over the Pacific Ocean about 30 miles from Vandenberg AFB, CA, took place on 11-12 December 1974. The object of the tests was to determine the ability of the dropsonde to measure stable atmospheric pressure, temperature, and humidity. The resulting data did not exhibit either accuracy or repeatability. The sondes reported total pressure changes of 445 to 564 mb when

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dropped from 500 mb to the surface pressure of 1020 mb, a change of 520 mb. For the same drop conditions, the sondes measured total temperature changes from 18.3° to 25.7°C as opposed to the known 27.9°C temperature change from -15.7° to +12.2°C. Compensation for initial thermistor stabilization and time response improved the temperature data. Objective comparisons of humidity data were not possible because the humidity calculations were a direct function of the reported temperature. The report concludes that the sonde, as it is currently manufactured, does not adequately measure the vertical profile of pressure, temperature, and humidity parameters.

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NCAR SONDE FLIGHT TEST REPORT

SECTION A — INTRODUCTION

Air Weather Service (AWS) has an operational requirement to obtain meteorological soundings to measure atmospheric pressure, temperature, and humidity from the flight level of weather reconnaissance aircraft to the earth's surface. AWS currently uses approximately 2000 dropsondes per year at an annual cost of $600K. Air Force Logistics Command (AFLC) established an "annual buy" procurement policy on this expendable item. Because of this policy, competition has increased and improved dropsonde designs have been developed. For AWS to have a modern dropsonde at the most competitive cost, comparative dropsonde data must be available to facilitate basic procurement decisions on whether to continue with old "reliable" designs, to invest development money, or better yet, to identify existing capabilities that may be readily available within industry.

The National Center for Atmospheric Research (NCAR) designed and developed a dropsonde that merits evaluation by AWS. The NCAR sonde was designed as a wind speed/direction measurement device along with measurement of the meteorological parameters of temperature, pressure, and humidity. On a 1973 competitive procurement, NCAR contracted to Dorsett Electronics for the manufacture of the "windsonde" to support the GATE Project, 1974 (Global Atmospheric Research Program/Atlantic Tropical Experiment). Under existing production or development Air Force contracts, comparative dropsonde performance data are readily available on all other operational dropsondes. To determine performance characteristics of the NCAR sonde, AWS flight tested 20 sondes on 11-12 December 1974. The flight test was limited to an evaluation of pressure, temperature, and humidity measurements; wind speed/direction measurements were not included since sufficient data were available through the National Oceanic and Atmospheric Administration (NOAA).

Flight Test Objectives

The objective of the flight test was to obtain comparative dropsonde performance data on the Dorsett Electronics' meteorological dropsonde. Specific objectives included the following:

a. Obtain temperature, humidity, and pressure data from the sonde's meteorological sensors for comparison with other sounding data.

b. Gain operational hands-on experience with the NCAR dropsonde and identify any potential problem areas, advantages, and disadvantages. Check the dropsonde compatibility with operational equipment and operational procedures.

c. Evaluate the sonde-to-receiver RF (radio frequency) link under actual sonde-to-aircraft slant ranges.

Approach

A WC-130 aircraft was specially instrumented to receive the dropsonde data which was recorded on a strip chart recorder. The airborne instrumentation used for the test was less than that which would be required for operational use, but it was sufficient to generate comparative data. Twenty of the Dorsett dropsondes were flight tested. To vary the fall time, four sondes were dropped using the large windsonde parachute (6-ft cross tee), and 16 sondes were dropped using the AN/AMT-13 dropsonde parachute (19-inch diameter). The data from the 20 test sondes were then compared for repeatability and accuracy. The flight-level pressure, temperature, humidity, winds, and height pressure (radar altitude) data were recorded for each drop. Two radiosonde observations (raobs) were made from Vandenberg AFB — one just before and one just after the test. These independent soundings were used as a standard with which to compare the NCAR data.
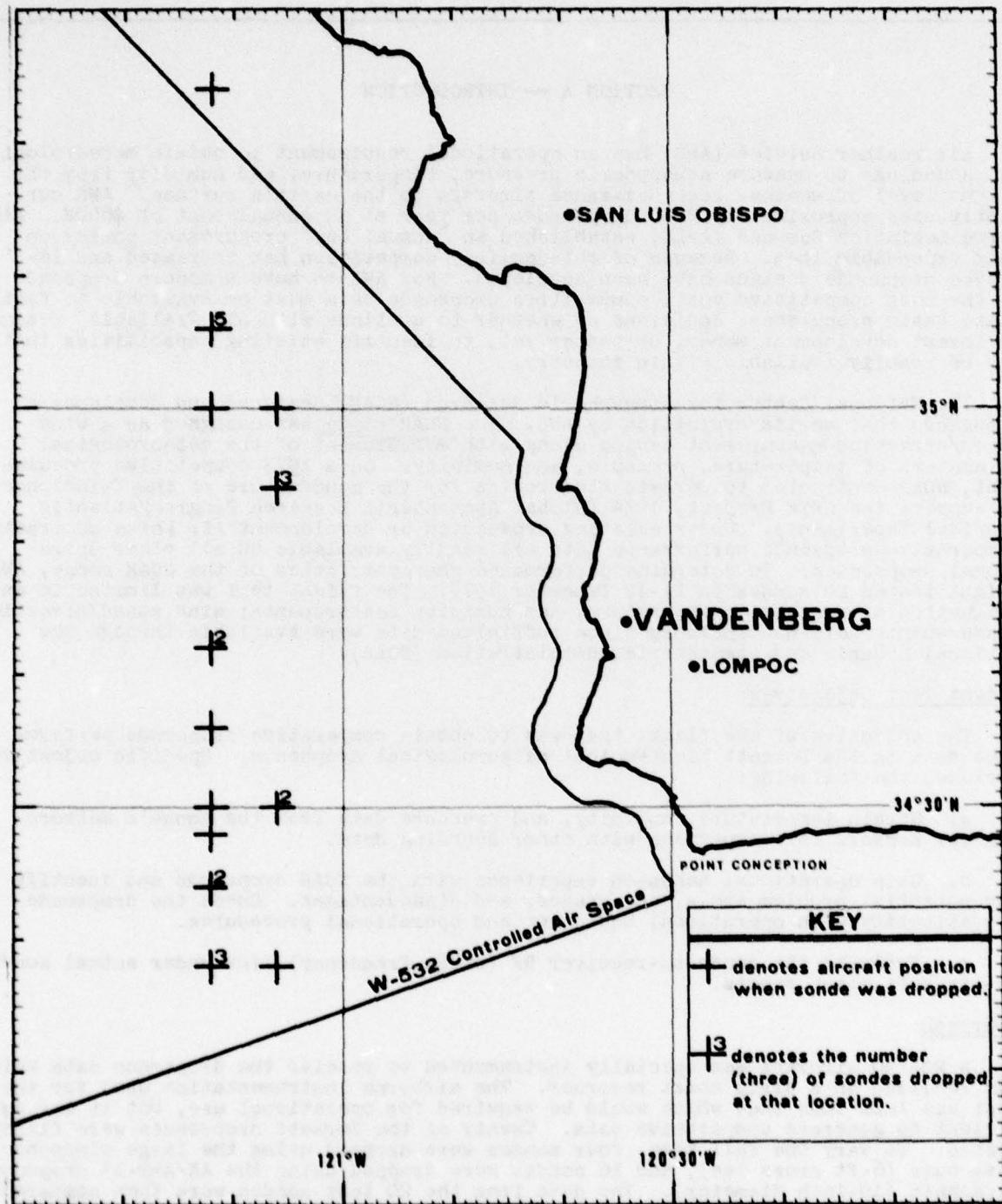
Figure 1.   Drop Zone.

SECTION B — METHOD OF CONDUCTING TEST

Air Weather Service established a Military Airlift Command (MAC) Service Test requirement to conduct an in-flight evaluation of the new NCAR-designed meteorological dropsonde instrument. The test was approved under MAC Service Test No. 597-AWS-WC 130-94000. The contractor, Dorsett Electronics, supported the test under Contract No. F11623-74-90236. The Western Test Range assigned controlled air space W-532 to the project, and the sondes were dropped approximately 30 miles off the coast of California (Figure 1). The 9th Weather Reconnaissance Wing (since deactivated) provided the crew and aircraft for the test flight.

The MAC Service Test authorized the installation of the dropsonde receiver/recorder instrumentation pallet and the required electrical connections. The instrumentation pallet was strapped down in the rear of the WC-130 cargo compartment near the dropsonde dispenser. Electrical connections were made to the aircraft 406 MHz antenna and to 60 Hz power (Figure 2). The Dorsett Electronics project engineer provided, installed, maintained, and operated the instrumentation pallet. The equipment was checked for proper operation prior to flight.

Standard reconnaissance procedures were used to conduct the test. The aerial reconnaissance weather officer (ARWO) recorded the flight-level observation for each drop. The horizontal observations were recorded on the AWS Form 24. These data appear in Appendix A. The flight-level data is summarized in Figure 3. The weather observer (WO) loaded and launched the sondes as required, and he recorded the four AN/AMT-13 vertical observations. Prior to dropping each NCAR test sonde, the contractor's project engineer calibrated
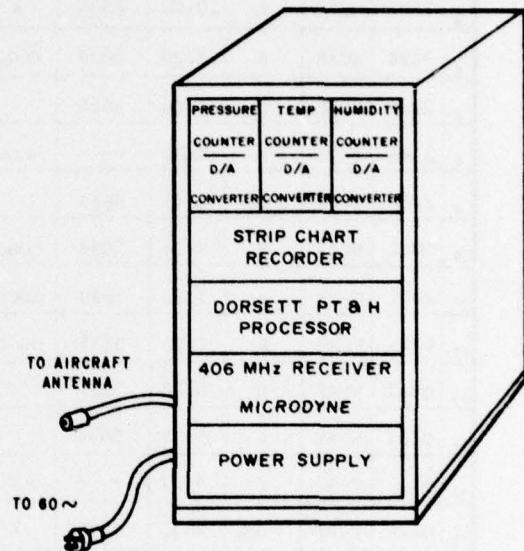
Figure 2. Dorsett Electronics Instrumentation Pallet.

Time (PST)		2124	2326	0126	0310
1301 A Pressure		500.3	499.5	498.3	498.2
Height of 500-mb Pressure Surface	Feet	18870	18840	18790	18810
	Meters	5752	5742	5727	5733
True Temperature		-15°C	-16°C	-15°C	-16°C
Dew-Point Temperature		Dry	-18°C	-23°C	-23°C
Winds (Direction/Speed)		300/15	340/20	310/25	320/30
Flight Conditions		Dark, No Moon	Dark, No Moon	Dark, No Moon	Dark, No Moon

Figure 3. Summary of Flight-Level Data.

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S E Q	PST	TYPE	CHUTE *	FALL TIME	SONDE #	DROP	REMARKS	POSITION	
								LAT	LONG
1	2123	NCAR	L	20:00	5620	GOOD		35.1	121.2
2	2148	T-13	/	4:20	———	GOOD		35.1	121.2
3	2207	NCAR	L	19:08	5584	GOOD		34.4	121.2
4	2233	NCAR	L	19:10	5613	GOOD	CALIBRATION FLIPPED	34.3	121.2
5	2302	NCAR	L	10:00	5536	X	PRESSURE PROBLEM/CHUTE FAIL	34.6	121.2
6	2326	NCAR	S	5:20	5629	GOOD		35.6	121.2
7	2340	NCAR	S	5:40	5628		RCVR MAL - TX FAILURE	34.3	121.2
8	2349	T-13	/	4:06	———	GOOD		34.9	121.1
9	2358	NCAR	S	5:41	5625		PRESSURE PROBLEM	35.0	121.2
10	0011	NCAR	S	5:34	5633	GOOD		34.9	121.1
11	0025	NCAR	S	5:23	5630	GOOD		35.1	121.2
12	0036	NCAR	S	5:20	5637	GOOD	DATA AFFECTED SLIGHTLY BY AIRCRAFT TURN AT 3½ MIN.	34.3	121.2
13	0047	NCAR	S	5:00	5631	GOOD		34.3	121.1
14	0101	NCAR	S	5:15	5634		FREQ. GEN LEFT ON - AFFECTED H DATA	34.7	121.2
15	0112	T-13	/	4:07	———	GOOD		34.5	121.1
16	0126	NCAR	SM	2:35	4176	X	GOOD SIGNAL TO SURFACE	35.1	121.2
17	0137	NCAR	SM	4:55	4111		NO TEMP DATA IN CHAMBER- DROPPED ANYWAY	34.5	121.1
18	0155	NCAR	SM	5:05	4121	GOOD		34.9	121.1
19	0210	NCAR	SM	2:51	4183	X	CHUTE FAILURE	34.7	121.2
20	0219	NCAR	SM	4:55	4214	GOOD		35.0	121.1
21	0236	NCAR	SM	4:50	4017		LOST H DATA ON LAUNCH (LOST HYGRISTOR)	34.4	121.2
22	0253	NCAR	SM	2:13	4039	X	CHUTE FAILURE	35.1	121.2
23	0303	NCAR	SM	4:36	4209		ACFT BANKED AT ≈3 MIN	34.4	121.2
24	0310	T-13	/	≈4:10	———	GOOD		34.5	121.2
25									

* L - LARGE DORSETT CHUTE
  S - SMALL AMT-13A CHUTE
  SM - SMALL AMT-13 CHUTE

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Figure 4. Flight Test Log, 11-12 Dec 1974, Western Test Range.

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the pressure, temperature, humidity, and frequency values on the strip chart re-corder. The test sondes were then released from the aircraft and the received meteorological data were plotted on the strip chart as the sonde descended.

The dropsonde strip chart data were reduced after the flight test. Dorsett Electronics provided procedures for reading the strip chart and calculating temper-ature, pressure, and humidity. AWS reduced the data for evaluation. The test results are described in the next section of this report.

The 6-hour test was conducted 11-12 December 1974 between the hours of 2100-0300 PST under stable weather conditions. Twenty NCAR and four AN/AMT-13 dropsondes were dropped from the 500-mb flight level. The Flight Test Log is shown in Figure 4.

SECTION C — RESULTS

Raw Data

The dropsonde meteorological data, as measured by the pressure (p), temperature (T), and humidity (H) transducers, were converted to frequencies and transmitted to the aircraft receiver/processor. The processor provided a three-channel (p, T, H) frequency output to the frequency counters which input to the three-channel strip chart was linear on 11-inch paper with 200 evenly spaced divisions. (Figure 5.)
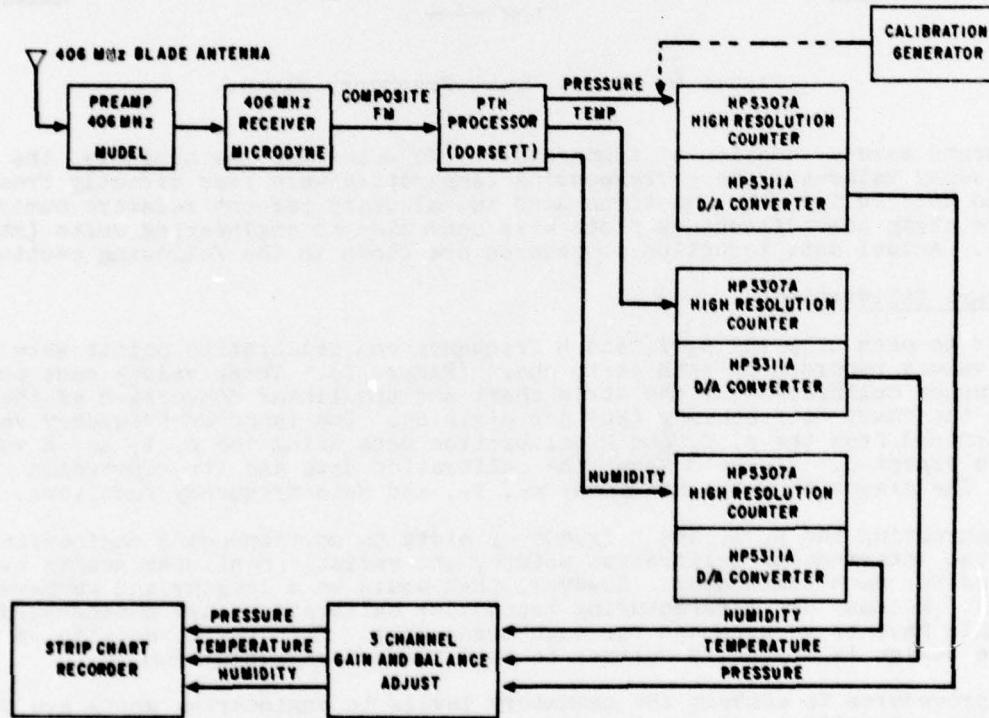
Figure 5. Airborne Receiver/Processor Block Diagram.

To use the strip chart frequency plots, the p, T, and H frequency scales were determined for each transducer, and the p, T, and H frequency values were then read directly off the chart (Figure 6). Pressure (mb) and temperature (°C) values were then calculated directly from the individual transducer calibration data. Humidity
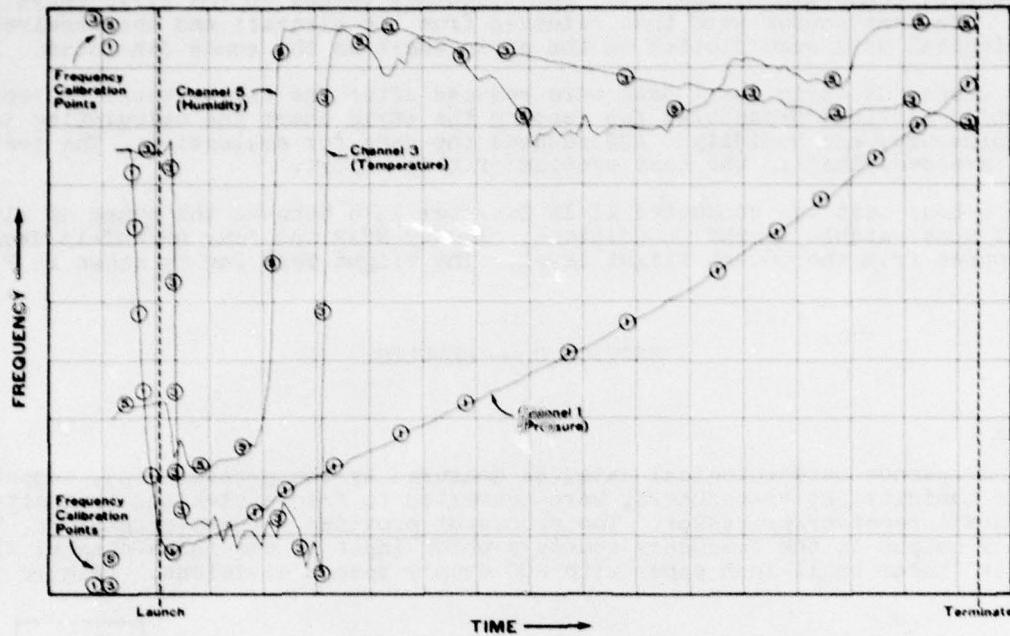
Figure 6. Strip Chart Frequency Plots.

measurements were a function of temperature. To determine the humidity, the humidity frequency value and the corresponding temperature were read directly from the chart and entered into the equations used to calculate percent relative humidity. Thus, the strip chart frequency plots were converted to engineering units (mb, °C, and %RH). Actual data reduction procedures are shown in the following section.

Strip Chart Calibration

Prior to each drop the p, T, and H frequency end calibration points were printed and the values recorded on each strip chart (Figure 7). These values made possible the frequency calibration of the strip chart and the linear conversion of the divisions on the chart to frequency (Hz) per division. The range of frequency values was determined from the p, T, and H calibration data using the p, T, and H values that were expected. Figure 8 shows the calibration data and its conversion to frequency. The graphs show the nonlinear p-, T-, and H-to-frequency functions.

By converting the p, T, and H frequency plots to corresponding engineering units for all the intermediate calibration points, the variable nonlinear scales could be determined for each transducer. However, that would be a lengthy and cumbersome procedure. Because the manufacturing transducer calibrations are nonstandard a scale would have to be produced for each transducer. This characteristic of the dropsonde design is discussed further in Data Comparison/Evaluation.

The procedures to convert the mandatory levels to engineering units are described in the next subsection. It was expedient to calculate from the calibration data the frequencies required for the 500-mb, 700-mb, 850-mb, and 1000-mb pressure measurements. The corresponding temperature and humidity values were then read and converted to engineering values.

For the frequency calibration of temperature the 1000- to 100,000-Hz frequency range is required. Therefore, the temperature frequency scales have a crossover at 10,000 Hz. The values for f_1 to f_2 ranged from 1000 Hz to 9999 Hz and the values for f_1' to f_2' ranged from 10,000 Hz to 100,000 Hz. This simply resulted in two

PRESSURE

Hertz

(calibration mark)

recorded freq (f_y)

1

Number of
divisions between
calibration marks (X)

200
divs.
Total

recorded freq (f_x)

1 (calibration mark)

time ———→

TEMPERATURE

Hertz

(calibration mark)

recorded freqs (f_y, f_y')

3

Number of
divisions between
calibration marks (X)

200
divs.
Total

recorded freqs (f_x, f_x')

3 (calibration mark)

time ———→

HUMIDITY

Hertz

(calibration mark)

recorded freq (f_y)

5

Number of
divisions between
calibration marks (X)

200
divs.
Total

recorded freq (f_x)

5 (calibration mark)

time ———→

Figure 7.   Strip Chart Calibration p, T, and H Parameters.

SONDE #5584

CAL PRESS	INTER-MEDIATE VALUE	MULTIPLICATION FACTOR	ACTUAL FREQUENCY (Hz)
149.58	2262.20		
198.02	2220.76		
245.97	2178.62		
293.98	2135.76		
340.87	2093.62		
386.55	2052.00		
434.32	2007.92		
481.83	1963.24	× 25	49,081
529.03	1918.40		
576.10	1872.79		
623.64	1925.70		
671.49	1777.07		
717.40	1728.49		
765.11	1675.95		
812.57	1620.90		
860.46	1561.72		
906.60	1500.49		
954.85	1430.29		
1001.88	1358.54		
1048.15	1284.00	× 25	32,100

END

CALIBRATION DATA
GENERATED DURING
MANUFACTURE
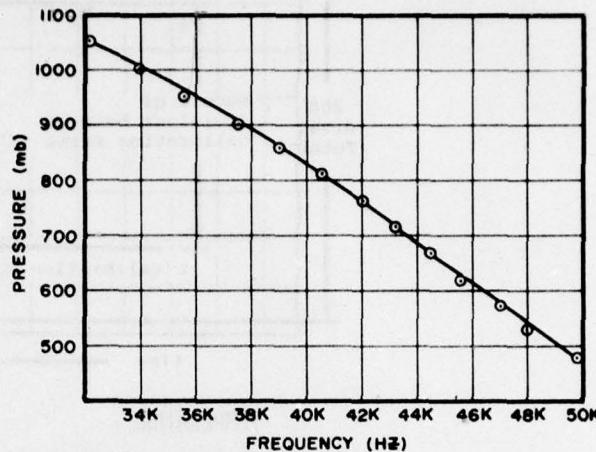
Figure 8a. Sonde #5584 Calibration Data and Conversion to Frequency for Pressure.

CALIBRATION TEMPERATURES GIVEN IN SEQUENCE (°C)	SONDE #5584 CAL TEMP VALUES	MULTIPLICATION FACTOR	ACTUAL FREQUENCY (Hz)
	11.85		
	13.10		
	14.79		
	17.15		
	20.48		
	24.93		
-30	30.85	× 100	3,085
-25	38.75		
-20	49.19		
-15	62.73		
-10	80.34		
-5	102.71		
0	131.59		
5	167.94		
10	213.61		
15	270.96		
20	340.70		
25	427.00		
30	531.93	× 100	53,193
35	659.59		
40	812.99		

END

CALIBRATION
DATA
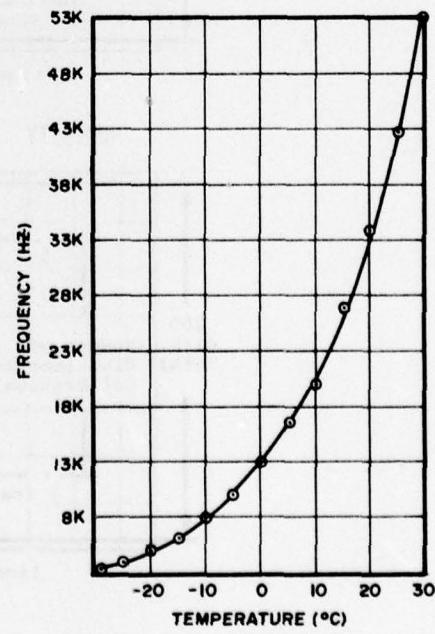
Figure 8b. Sonde #5584 Calibration Data and Conversion to Frequency for Temperature.

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SONDE #5584 CALIBRATION RESIST-ANCE VALUES FOR 33% RH at 25°C	MULTIPLICATION FACTOR	ACTUAL FREQUENCY (Hz)
28.84	x 400	11,536
30.72		
34.22		
37.25		
41.60		
43.65		
45.19		
47.28		
49.57		
56.14		
61.25		
67.15		
74.02		
81.78		
89.88		
100.85		
113.09		
126.82		
139.43		
152.96		
168.10	x 400	67,240

END

CALIBRATION DATA
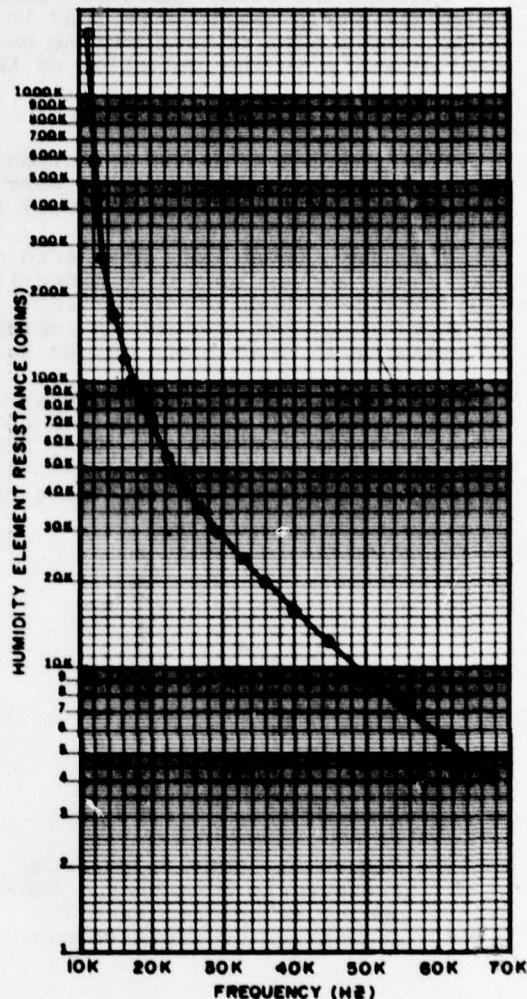
Figure 8c.   Sonde #5584 Calibration Data and Conversion to Frequency for Relative Humidity.

frequency scales for each temperature plot. For sonde #5584 this frequency calibra-tion values ranged from 1055.8 to 9972.2 Hz and from 10,558 to 99,722 Hz. These ranges converted to 0.14°C/division for the lower range (f_1, f_2) and to 0.35°C/divi-sion for the upper range (f_1', f_2'). This was good resolution.

For the frequency calibration of pressure the 30,000- to 45,000-Hz range of values was needed. With 200 divisions on the strip chart paper, this equated to 75 Hz/division. But, because the pressure-to-frequency function was nonlinear, the millibar/division values ranged from approximately 2 mb/division to 3 mb/division.

For the frequency calibration of humidity the 10,000- to 67,000-Hz range of values was needed, and for 200 divisions this equated to 285 Hz/divisions. Humidity element resistance values increased exponentially as the humidity increased, and the resistance values varied as a function of temperature. For actual data reduction the percent RH/division ranged from approximately 0.5% RH/division at the lower humidities to 1.0% RH/division at the higher humidities.

Overall the strip chart resolution was sufficient for these test purposes. Because the strip charts were read in frequency and then converted to engineering units, the scales of engineering units as would appear on the strip chart were not used directly in the reduction of the data.

Conversion to Engineering Units

For purposes of sonde performance evaluation, the mandatory levels as measured by the NCAR-designed dropsonde were calculated and tabulated. The mathematical procedures are described in detail to insure that the data are not misrepresented.

Thus far, these data have been described as frequency plots. A tabulation of the direct conversions to engineering units will establish a common departure point for various methods of comparison. The p, T, and H data resulting from the direct conversion did not accurately represent the known atmospheric conditions. Various adjustments to these data may be warranted, but the ground rules must be understood.

The dropsonde pressure data were used as an absolute, i.e., the frequency corresponding to 500 mb was used as the 500-mb level on the strip chart. The calculations to convert the 500-, 700-, 850-, and 1000-mb levels to frequency were linear interpolations of the pressure-to-frequency calibration data. Figure 9 and the following calculations illustrate how the frequencies were determined.

$$\frac{p_h - p_a}{p_h - p_\ell} = \frac{f_a - f_\ell}{f_h - f_\ell}$$

$$f_a - f_\ell = \frac{p_h - p_a}{p_h - p_\ell} f_h - f_\ell$$

$$f_a = f_\ell \quad \frac{p_h - p_a}{p_h - p_\ell} f_h - f_\ell$$
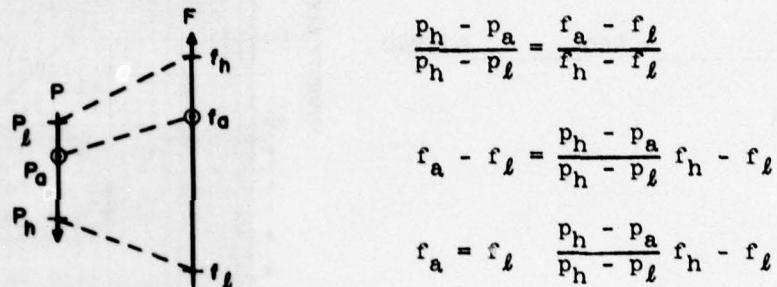
Figure 9. Conversion from Pressure to Frequency. Frequency values increase for decreasing pressure values.

p_ℓ = lower calibration pressure value

p_h = higher calibration pressure value

p_a = mandatory pressure value, p_ℓ, p_a, p_h

f_h = higher calibration frequency value (frequency of p_h)

f_ℓ = lower calibration frequency value (frequency of p_ℓ)

EXAMPLE: Sonde #5584 for 850 mb

$$f_a = 1561.72 + \frac{860.46 - 850.00}{860.46 - 813.57} (1620.90 - 1561.72)$$

$$f_a = 1561.72 + \frac{10.46}{47.89} (59.18)$$

$$f_a = 1561.72 + 12.93$$

$$f_a = \underline{1572.65 \text{ Hz}}$$

This same equation, in the form shown below, was used to calculate sea-level pressure.

$$p_a = p_h - \frac{f_a - f_\ell}{f_h - f_\ell} (p_h - p_\ell)$$

The pressure plot graph was extended on the strip chart to a vertical line drawn to show the surface or sonde termination (Figure 10). Sonde termination was established by the last data print #1, 3, or 5. The data were sampled and printed in a 1, 3, 5 (p, T, and H) sequence with 3 seconds between each print. Therefore, for a sonde falling at 25 ft/sec (large parachute), 3 seconds will equate to approximately 3 mb near the surface. For the 75 ft/sec fall rate (small parachute), 3 seconds will equate to approximately 9 mb. The final step in determining the sea-level pressure was to read the surface pressure frequency value and calculate that pressure (p_a). The sea-level pressure data varied from 968.9 to 1035 mb. Therefore, it was important to consider possible adjustments to these data. After the pressure is converted to frequency, then the corresponding temperature and humidity frequencies are identified and the engineering values computed.
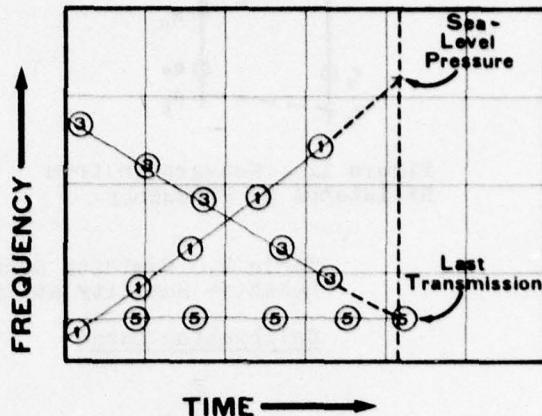
Figure 10. Determination of Sea-Level or Surface Pressure.
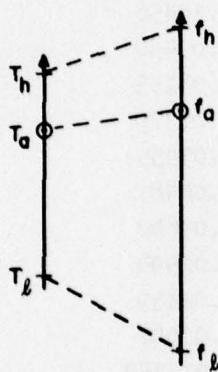
Figure 11. Conversion from Temperature to Frequency.

$$\frac{T_a - T_\ell}{T_h - T_\ell} = \frac{f_a - f_\ell}{f_h - f_\ell}$$

$$f_a - f_\ell = \frac{T_a - T_\ell}{T_h - T_\ell} (f_h - f_\ell)$$

$$f_a = f_\ell + \frac{T_a - T_\ell}{T_h - T_\ell} (f_h - f_\ell)$$

The above formula used to convert frequency to temperature values is the same linear interpolation used for pressure. For temperature, the frequency increases with increasing temperature (Figure 11). Once again the f_h and f_ℓ values are the calibration frequencies for the temperature values which are on either side of T_a.

Two equations were used to calculate the relative humidity. The first equation was used to calculate the percent relative humidity at 25°C without temperature correction. The second equation applied the necessary temperature corrections. Tables 1 and 2 provided by the Dorsett Electronics were required for these calculations. The following steps were used to calculate humidity:

Step 1: The humidity frequency (f_a) was read from the strip chart.

Step 2: F_a was computed. $F_a = \frac{f_a}{400}$

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Step 3: Humidity element resistance, R_a, was calculated by interpolating off the calibration data sheet (Figure 12).

$$F_a = \frac{f_a}{400}$$

$$R_a = R_\ell + \frac{F_a - F_h}{F_\ell - F_h}(R_h - R_\ell)$$
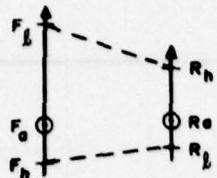
Figure 12. Conversion from Resistance to Frequency.

Table 1. Humidity Sensor Resistance Values for 33% Relative Humidity at 25°C for #5584.

Calibration Data*	Resistance Values
F	R (meg ohms)
28.84	1.6400
30.72	0.6004
34.22	0.2702
37.25	0.1812
41.60	0.12147
43.65	0.10456
45.19	0.09450
47.28	0.08153
49.57	0.07370
56.14	0.05455
61.25	0.04481
67.15	0.03660
74.02	0.02998
81.78	0.02439
89.88	0.02007
100.85	0.015753
113.09	0.0122752
126.82	0.0094079
139.43	0.0074106
152.96	0.0057232
168.10	0.0042870

*Calibration data correspond to resistance values by position.

Step 4: Compute the ratio K_a.

$$K_a = \frac{R_a}{10,000 \text{ ohms}}$$

For 20,000-ohm humidity elements (sondes #4176, 4111, 4121, 4183, 4214, 4017, 4039, and 4209)

$$K_a = \frac{R_a}{20,000 \text{ ohms}}$$

This is the ratio of the resistance (R_a) at the actual relative humidity and temperature (T_a) of the resistance of a humidity element at 33% relative humidity and 25°C.

Step 5: Find K_a on the table below and read the percent relative humidity, H_a, or interpolate for H_a.

$$H_a = H_\ell + \frac{K_a - K_\ell}{K_h - K_\ell}(H_h - H_\ell) = \%RH$$

Table 2. Ratio of Resistance at Actual Relative Humidity and Temperature to that at 33% Relative Humidity and 25°C.

+40°C	25°C	0°C	-40°C	%RH
0.61	0.585	0.55	0.52	10
0.72	0.695	0.65	0.62	15
0.82	0.800	0.78	0.74	20
0.89	0.875	0.85	0.82	25
0.95	0.940	0.92	0.90	30
1.00	1.00	1.00	1.00	33
1.04	1.05	1.06	1.10	35
1.15	1.175	1.23	1.3	40
1.27	1.32	1.40	1.63	45
1.47	1.58	1.75	2.23	50
1.85	2.00	2.35	3.1	55
2.3	2.50	3.1	4.2	60
3.0	3.25	4.1	6.5	65
4.0	4.5	6.0	10.2	70
6.5	7.3	9.8	17.	75
10.	12.0	17.	29.	80
16.	18.5	26.	--	85
23.	29.	44.	--	90
40.	60.	86.	--	95
126.	140.	170.	--	100

Because the tabulated mandatory level data were sufficient to evaluate sonde performance, the significant levels were not identified from the strip chart plots. Special knowledge of each strip chart plot and individual judgment would be required to identify the significant levels and to produce the data required to plot the adiabatic charts. The mandatory data are tabulated in the next subsection.

Tabulated p, T, and H Data

The reduced p, T, and H mandatory level data are shown in Table 3. Included in the table are the raob and AN/AMT-13 measurements which provided the comparative

Table 3. Temperature and Humidity Data for Corresponding Mandatory Levels Without Adjustment.

PRESSURE LEVEL		RAOB 1845 PST	NCAR #5620	T-13 #1	NCAR #5584	NCAR #5613	NCAR #5536	NCAR #5629	NCAR #5628	T-13 #2	NCAR #5625	NCAR #5613	NCAR #5630	NCAR #5637
Transmitted Sonde Press at Launch		—	467.6	—	513.9	456.5	M	492.1	577.0	—	M	456.4	474.8	499.3
500 mb	HEIGHT (m) (Note 4.)	5746	5772	5752	5778	5755	—			5739				
	TEMP (5.)	-15.7	-9.4	-16.0	-7.9	-9.0	M	-11.1@ (514.8)	-11.4	-16.0	+5.2	-10.6	-12.1	-12.4
	%RH	17	17	20	17	18	M	44	M	65	21	35	34	30
700 mb	HEIGHT (m)	3121	3129	3122	3067	3092	—			3125				
	TEMP	2.0	1.2	0.3	5.8	2.2	M	0.67	-3.6	0.9	M	1.9	0.3	2.2
	%RH	44	89	96	76	28	M	74	M	67	M	57	83	66
850 mb	HEIGHT (m)	1529	1546	1537	1462	1499	—			1534				
	TEMP	9.0	6.8	8.0	13.0	10.3	M	8.9	7.9	9.4	—	10.4	8.8	10.2
	%RH	61	(100+)	91	90	27	M	81	M	79	M	68	83	66
1000 mb	HEIGHT (m)	171	196	175	79	141	—			174				
	TEMP	12.7	11.5	12.7	→	11.8	M	11.8	11.0	11.9	M	11.7	11.6	11.6
	%RH	91	(100+)	95	99	99	M	96	M	95	M	(100+)	(100+)	(100+)
Sea Level	PRESS	1020	1029	1021	997	1011	M	1022	1022	1020	M	1010	1021	1035
	TEMP	12.0	11.9	12.8	17.4	11.7	M	12.5	12.1	12.8	M	12.2	11.5	12.0
	%RH	91	(100+)	95	97	99	M	96	M	95	M	(100+)	(100+)	(100+)
							NO PRESS SIGNAL		NO HUM CAL MARKS		NO PRESS DATA			

NOTES:

1. M denotes missing data.
2. When TEMP is in ( ) the TEMP was read at the pressure indicated in ( ) above.
3. When %RH is in ( ) the hygrister resistance was at a value that indicated 100+.
4. Height of the 500-mb level was determined using aircraft measurements.
5. The temperature values listed in this row were taken after the temperature measurements stabilized. If the first stabilized temperature occurred after a sonde measured pressure of 500 mb, that pressure was also listed.

Table 3. Temperature and Humidity Data For Corresponding Mandatory Levels Without Adjustment. (cont'd)

PRESSURE LEVEL		NCAR #5631	NCAR #5634	T-13 #3	NCAR #4176	NCAR #4111	NCAR #4121	NCAR #4183	NCAR #4214	NCAR #4017	NCAR #4039	NCAR #4209	T-13 #4	RAOB 0330 PST
Transmitted Sonde Press at Launch		486.0	474.8	----	465.8	M	468.6	475.4	475.6	M	475.9	477.6	----	
	HEIGHT (m) Note 4.			5742									5733	5738
500 mb	5. TEMP	-12.5@ (508.3)	-9.9@ (504.1)	-16.0	-12.5@ (536.6)	M	-13.8@ (555.6)	-11.7@ (552.8)	-11.9@ (505.8)	-11.1@ (630.9)	-12.4@ (516.0)	-11.7@ (524.3)	-16.0	-15.1
	% RH	47	41	78	62	M	93	67	41	M	45	35	54	39
	HEIGHT (m)			3170									3114	3118
700 mb	TEMP	3.8	2.2	1.6	1.38	M	2.3	1.9	1.1	2.4	1.5	1.5	1.7	1.3
	% RH	68	50	65	47	M	46	42	52	M	53	39	42	38
	HEIGHT (m)			1524									1523	1527
850 mb	TEMP	11.8	10.2	10.5	9.9	M	9.6	10.2	9.1	11.4	10.4	10.9	10.3	10.3
	% RH	78	71	62	80	M	78	60	(100+)	M	82	37	42	65
	HEIGHT (m)			162									164	168
1000 mb	TEMP	→	12.5	12.0	11.8	M	4.5	12.0	12.3	13.1	→	11.8	12.6	13.0
	% RH	(100+)	(100+)	100	(100+)	M	86	(100+)	93	M	(100+)	(100+)	92	72
	PRESS	968.9	1026.5	1019	1029.7	1017.7	1004.5	1020.1	1016.2	1002.1	999.6	1010.6	1019	1020
Sea Level	TEMP	13.2	12.3	12.4	11.7	M	4.5	12.0	11.8	13.2	12.4	11.5	12.6	11.7
	% RH	100	(100+)	100	(100+)	M	85	(100+)	(100+)	M	93	(100+)	95	72

NO TEMP SIGNAL (NCAR #4111)   NO HUM SIGNAL (NCAR #4017)

NOTES:

1. M. denotes missing data.
2. When TEMP is in ( ) the TEMP was read at the pressure indicated in ( ) above.
3. When % RH is in ( ) the hygrister resistance was at a value that indicated 100%+.
4. Height of the 500-mb level was determined using aircraft measurements.
5. The temperature values listed in this row were taken after the temperature measurements stabilized. If the first stabilized temperature occurred after a sonde measured pressure of 500 mb, that pressure was also listed.

data. Entries in the table are listed in time sequence. For the reasons noted, values from four sondes (#5536, 5628, 5625, and 4111) were not used for comparison or evaluation. Referring to the Flight Test Log (Figure 4), the fall times indicated that four parachutes (#5536, 4176, 4183, and 4039) failed to open fully, and of these four only the data from sonde #5536 were discarded. Two independent sources reliably measured pressure and temperature at 500 mb and at sea level. This being the case, it was desirable to give these two levels primary consideration. The Vandenberg raob and aircraft measurements were used for upper-air comparisons while Vandenberg AFB weather station and T-13 dropsonde data were used for the sea-level comparisons. Analysis of the test data revealed large inconsistencies between the transmitted sonde pressures at time of launch and the aircraft-sensed pressures. It is theorized that a reduced pressure exists in the lower end of the launch tube. Because of this, only pressures at sea level are considered for evaluation. Temperatures are evaluated at both levels and were taken from the tabulated data (Table 3) to establish reliability of sonde performance. Adiabatic chart plots and computations are used in the next subsection to provide additional analysis and evaluation of sonde performance. Since the weather conditions varied only slightly during the 6-hour flight test, the temperature and pressure measurements from the independent sources were confined to establish one set of pressures and temperatures for comparison purposes. The measurements are summarized in Table 4. The mean was used as a standard about which to determine the performance of the NCAR-designed dropsonde. The test condition variations and the inaccuracies of the independent measurements were combined to establish an uncertainty for the standard.

Flight level observations reported that the height of the 500-mb level gradually lowered from 18,890 feet to 18,790 feet, which may be explained by the diurnal effect. Flight level winds were relatively constant with a norm of 20 knots from 320 degrees. The air mass was reasonably dry and stable during the entire period. The flight level pressure was measured for each drop using the 1301 Pressure Transducer (accuracy: ±1.5 mb). The absolute pressure readings at flight level ranged from 498.0 mb to 500.3 mb and the mean was 499 mb. Although the pressures at launch were not considered for evaluation, a discussion of what was found is important. The data is retained (see Table 5) for historical purposes. If the hypothesis is accepted that a reduced pressure does, in fact, exist below the release gate of the dispenser, the sensor response and sensitivity is extremely favorable; an important plus factor in the performance of the sonde. Note also that all except two initial transmitted pressures are lower than the aircraft observed pressures indicating a consistency to sense pressures on the low side.

AN/AMT-13 dropsonde sea-level pressure measurements varied from 1019 to 1021 mb, and the Vandenberg AFB weather station reported a constant 1020.2 mb. The mean of 1020 mb was used as the test condition or standard for the sea-level pressure measurements and an uncertainty of ±1 mb was assigned.

The temperatures measured at 500 mb varied from -15.7°C to -17.0°C, and the mean used for the standard was -15.7°C. The uncertainty is equal to the sum of ±1.5°C for actual temperature variations and ±1°C for measurement errors giving a total of ±2.5°C. The sea-level temperature measurements ranged from 11.7 to 12.8°C and had a mean of 12.2°C. Uncertainty for the sea-level standard of 12.2°C summation of actual temperature variation (±0.6°C) and measurement error assumed to be not greater than ±1.0°C, giving ±1.6°C.

Humidity measurements varied too widely to allow quantitative evaluation. Observations of the humidity data are discussed in the next subsection.

Data Comparison/Evaluation

Listed below are the manufacturer's basic specifications for the test sondes. Good sonde performance would be shown by accurate measurements of the known conditions, but Tables 5 and 6 show a wide variation in the pressure and temperature measurements.

Table 4. Summary of Independent Pressure, Temperature, and Humidity Measurements.

		ROAB 1845 PST	AN/AMT-13A			Flight Level			VAND ROS.			RAOB 0330 PST	MEAN	UNCER-TAINTY
			min	max	mean	min	max	mean	2158 PST	2257 PST	mean			
Height of 500-mb Level	feet	18852	18810	18870	18840	18790	18890	18830	—	—	—	18825	18835	—
	(m)	5746	5733	5752	5742	5727	5758	5741	—	—	—	5738	5741.8	
Press at Launch (mb)		—	—	—	—	498.0	500.3	499.0	—	—	—	—	499.0	±2.5
Sea-Level Press (mb)		1020	1019	1021	1019.8	—	—	—	1020.2	1020.2	1020.2	1020	1020	±1.0
Temp at 500 mb (°C)		-15.7	-16.0	-16.0	-16.0	-15.0	-17.0	-16.0	—	—	—	-15.1	-15.7	±2.5
Sea-Level Temp (°C)		12.0	12.4	12.8	12.7	—	—	—	11.7	12.8	12.3	11.7	12.2	±1.6
RH at 500 mb (%)		17	20/65/78/54			DRY			—	—	—	39	—	
RH at Sea Level (%)		91	95/95/99/93			—			83%	74%	—	72	—	
WIND	Dir	M				300°	310°	—	030°	320°	—	357°	—	
	Speed (kt)	M				15	35	—	02	05	—	13	—	
SKY COVER		—				—			25000 Thin SCTD	25000 Thin SCTD	—	—	—	

Table 5.   Initial Launch and Sea-Level Pressure Measurements.

SONDE #	Transmitted Sonde Pressure at Launch	Error from 499 mb	Sea-Surface Pressure	Error from 1020 mb	Total Press Change
	(mb)	(mb)	(mb)	(mb)	(mb)
5620	467.6	31.4	1029.0	9.0	561.4
5584	513.9	14.9	997.0	23.0	483.1
5613	456.5	42.5	1010.6	9.4	554.1
5536*	missing	————	————	————	————
5629	492.1	6.9	1021.7	1.7	529.6
5628	577.0	78.0	1022.0	2.0	445.0
5625*	missing	————	————	————	————
5633	456.4	42.6	1010.5	9.5	554.1
5630	474.8	24.2	1020.6	0.6	545.8
5637	499.3	0.3	1035.5	15.5	536.2
5631	486.0	13.0	968.9	51.1	482.9
5634	474.8	24.2	1026.5	6.5	551.7
4176	465.8	33.2	1029.7	9.7	563.9
4111*	missing	————	1017.1	2.9	————
4121	468.6	30.4	1004.5	15.5	535.9
4183	475.4	23.6	1020.1	0.1	544.7
4214	475.6	23.4	1016.2	3.8	540.6
4017*	missing	————	1002.1	17.9	————
4039	475.9	23.1	999.6	20.4	523.7
4209	477.6	21.4	1010.6	9.4	533.0
Mean 16	483.5	27.1	1013.9	11.7	530.3
Std Dev 16	29.0	17.7	16.2	12.5	32.7
Mean 8	485.5	17.2	1015.1	9.3	529.5
Std Dev 8	14.6	9.1	12.5	9.2	20.2
Mean 4	485.6	13.5	1019.2	9.4	533.5
Std Dev 4	11.9	11.7	14.7	10.0	9.0

* - denotes the four sondes that had missing data and were unusable.

Table 6.   Initial Launch and Sea-Level Temperature Measurements.

SONDE #	1st Stabilized Temp. after Launch	Error from -15.7°C	Sea-Surface Temperature	Error from 12.2°C	Total Temp. Change
	(°C)	(°C)	(°C)	(°C)	(°C)
5620	-9.4	6.3	11.9	0.3	21.3
5584	-7.9	7.8	17.4	5.2	25.3
5613	-9.0	6.7	11.7	0.5	20.7
5536*	missing	————	————	————	————
5629	-11.1	4.6	12.5	0.3	23.6
5628	-11.4	4.3	12.1	0.1	23.5
5625*	+5.2	20.9	missing		
5633	-10.6	5.1	12.2	0	22.8
5630	-12.1	3.6	11.5	0.7	23.6
5637	-12.4	3.3	12.0	0.2	24.4
5631	-12.5	3.2	13.2	1.0	25.7
5634	-9.9	5.8	12.3	0.1	22.2
4176	-12.5	3.2	11.7	0.5	23.2
4111*	missing	————	————	————	————
4121	-13.8	1.9	4.5	7.7	18.7
4183	-11.7	4.0	12.0	0.2	23.7
4214	-11.9	3.8	11.8	0.4	23.7
4017*	-11.1	4.6	13.2	1.0	24.3
4039	-12.4	3.3	12.4	0.2	24.8
4209	-11.7	4.0	11.5	0.7	23.2
Mean 16	-11.2	4.4	11.3	1.1	23.1
Std Dev 16	1.4	1.4	2.3	2.0	1.7
Mean 8	-11.4	4.3	12.6	0.9	24.0
Std Dev 8	1.4	1.4	1.9	1.7	0.7
Mean 4	-11.9	3.8	12.2	0.2	24.1
Std Dev 4	0.6	0.6	0.2	0.05	0.5

* - denotes the four sondes that had missing data and were unusable.

SPECIFICATIONS

	Pressure Sensor	Temperature Sensor	Humidity Sensor
Range	150 to 1060 mb	-55 to +40°C	10 to 100% RH
Accuracy	±2 mb	±0.5°C	±5 to ±13% RH

Because of the wide variation of moisture conditions, it was not possible to quantitatively evaluate the reliability of the humidity measurements. The four AN/AMT-13 humidity measurements at 500 mb were 20, 65, 78, and 54% relative humidity. There were no cloud layers between flight level and the surface. The humidity data on Table 3 followed the same trends for the various levels. The significant levels at 700 and 850 mb were identified on the humidity frequency plots. Because the humidity measurements are dependent upon the temperature measurements, the temperature measurements must be accurate before the reliability of the humidity measurements can be determined.

The sea-surface pressure and temperature measurements should have been the most reliable. Six sondes measured the surface pressure to within ±4 mb, but the standard deviations of 12.5 and 14.7 mb are too large to establish any reliability. Surface temperature measurements were the most reliable and they were well within limits required for operational acceptability. Only two sondes had bad temperature data at the surface. Surface humidity measurements were good and were within limits (±10% relative humidity) for operational acceptability. Plotting and computation of the adiabatic charts showed that the temperature measurements were also reliable at the upper levels. The standard deviations of 1.4 and 0.6°C on Table 6 show measurement reliability.

The four sondes that failed were unusable because of a loss of either the temperature or pressure data. Three of the failures had erratic temperature data. No specific causes for the failures were identified. Of the remaining 16 sondes, there were no indications of malfunction.

To further evaluate sonde performance, data from each NCAR sonde were plotted on adiabatic charts. Mean virtual temperatures were calculated and thicknesses between each layer computed by means of height tabs printed on the charts. The altitude of each standard isobaric surface was found by subtracting the thickness of each stratum from the top of the layer. The reference level, or beginning layer, was computed from data obtained by aircraft meteorological sensors. Sea-level pressures were computed utilizing the 1000-mb height, mean virtual temperature, and appropriate data reduction tables. Since confidence of a reliable SLP is based upon the close agreement of the transmitted SLP (adjusted for segments) and computed SLP, a comparison was made between these two measurements. To arrive at an acceptable error for evaluation, a ±2 mb was allowed for uncertainties in plotting the adiabatic charts. Added to the specification accuracy of the pressure sensor (±2 mb), a ±4 mb was selected as the acceptable difference between computed and last transmitted SLPs. Using these criteria, four sondes were selected as reliably sensing the true sea-level pressure. When compared to the known SLP, Table 7 shows that the temperature adjusted SLPs in column 3 were very close for 13 sondes. However, the differences shown in column 4 lower confidence in the sonde to accurately sense pressure in data-void areas.

Table 8 shows computed heights and temperatures sensed by all sondes used for evaluating performance. Also shown are the surface data calculations adjusted for segments. The standard deviations calculated for the NCAR sondes are considered too large to establish reliability of the pressure sensor. On the other hand, the temperature curves of the NCAR sonde show a greater variability but are comparable to the AN/AMT-13s and the Vandenberg raobs. The temperature sensor is reliable and responsive to rapid changes. In fact, the closeness of the computed sea-level pressure is attributed to the accuracy of the temperature sensor. In conclusion, additional engineering efforts are required to successfully develop a reliable, accurate pressure sensor for the NCAR sonde.

Table 7. Last Transmitted and Computed Sea-Level Pressures (SLP).

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
			Internal			
SONDE	Last Trans.	Computed	Difference	AN/AMT-13	Difference	Difference
#	SLP	SLP	Col. 2 & Col. 3	Data	Col. 3 & Col. 5	Col. 2 & Col. 5
	(mb)	(mb)	(mb)	(mb)	(mb)	(mb)
5620	1029.0	1024	+5.0	1021	+3.0	+8.0
5584	997.0	1009	-12.0	1021	-12.0	-24.0
5613	1010.6	1017	-6.4	1021	-4.0	-10.4
5536	———	———	———	———	———	———
5629	1021.7	1018	+3.7	1021	-3.0	+0.7
5628	1022.0	1028	-6.0	1021	+7.0	+1.0
5625	———	———	———	———	———	———
5633	1010.5	1017	-6.5	1021	-4.0	-10.5
5630	1020.6	1018	-2.6	1021	-3.0	-0.4
5637	1035.5	1018	+17.5	1019	-1.0	+16.5
5631	968.9	* 1013	-44.1	1019	-6.0	-50.1
5634	1026.5	1016	+10.5	1019	-3.0	+7.5
4176	1029.7	1018	+11.7	1019	-1.0	+10.7
4111	———	———	———	———	———	———
4121	1004.5	1024	-19.5	1019	+5.0	-14.5
4183	1020.1	1019	+1.1	1019	+0.0	+1.9
4214	1016.2	1017	-0.8	1019	-2.0	-2.8
4017	———	———	———	———	———	———
4039	999.6	1017	-17.4	1019	-2.0	-19.4
4209	1010.6	1018	-7.4	1019	-1.0	-8.4

* Early termination - extrapolated SLP.

SECTION D —CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The NCAR-designed dropsonde was capable of detecting the pressure, temperature, and humidity changes as the sonde fell successfully transmitting the data to an airborne receiver. Improvements in the accuracy of the sonde measurements will be required before the operational potential can be established.

Overall, the flight testing of the sondes was a success and the sample of sondes dropped was sufficiently large to obtain comparative data. The time frame and location of the drops were sufficiently close to readily identify internal consistency and accuracy. Based upon repeated pressure errors of greater than 4 mb and temperature errors of greater than 2°C, it must be concluded that under the flight test conditions the sonde was unreliable.

Pressure, temperature, and humidity data shifts were noted when the aircraft banked and turned. This condition was inherent to the FM signal and the airborne processor did not compensate for the signal drift.

The sondes cleared the aircraft dispenser and dispensing tube on every drop. Without shock and vibration test data on the sonde, the total effects of the dispenser cannot be evaluated. No operational handling problems were noted.

The data does not show any difference between the sondes dropped using the 6-foot or the 18-inch parachutes. A parachute release timer, allowing a 6-second delay was used with each sonde.

The humidity test results were inconclusive because of the pressure and temperature measurement errors. Pressure levels were not consistently identified which introduced too much uncertainty for any credible quantitative evaluation.

Table 8. Temperature and Computed Height Data.

PRESSURE LEVEL		ROAB	NCAR 5620	T-13 #1	NCAR 5584	NCAR 5613	NCAR 5629	NCAR 5628	T-13 #2	NCAR 5633	NCAR 5630	NCAR 5637	NCAR 5631	NCAR 5634	T-13 #3
500 mb	HGT (m)														
	TEMP (°C)	-15.7	-16.8	-15.9	-7.8	-9.0	---	-16.0	-16.0	-10.8	-12.2	---	---	---	-15.9
	RH (%)	17	17	20	18	18	---	---	65	35	34	---	---	---	79
700 mb	HGT (m)	3121	3129	3122	3067	3092	3090	3144	3125	3091	3092	3100	3081	3080	3120
	TEMP (°C)	+2.0	+1.2	+0.2	+5.8	+2.3	+0.7	-3.8	+1.0	+1.9	+0.2	+2.1	+3.7	+2.2	+1.6
	RH (%)	44	89	96	77	28	---	---	68	58	83	65	58	50	65
850 mb	HGT (m)	1529	1546	1537	1492	1499	1505	1576	1534	1497	1507	1507	1477	1487	1524
	TEMP (°C)	+9.0	+6.8	+8.0	+13.0	+10.4	+8.9	+7.8	+9.4	+10.5	+8.8	+10.2	---	+10.2	+10.5
	RH (%)	61	100	91	90	28	---	---	79	68	83	65	58	71	62
1000 mb	HGT (m)	171	196	175	79	141	149	227	174	138	152	149	109	127	162
	TEMP (°C)	+12.7	+11.4	+12.6	+17.5	+11.8	+11.9	+10.9	+12.0	+11.9	+11.6	+11.5	---	+12.5	+12.0
	RH (%)	91	100	95	98	100	---	---	94	100	100	100	---	100	---
SURFACE	SLP (mb)	1020	1024	1021	1009	1017	1018	1028	1021	1017	1018	1018	---	1016	1019
	TEMP (°C)	+12.0	+11.9	+12.8	+17.7	+11.6	+12.4	+11.9	+12.9	+12.1	+11.5	+12.0	---	+12.4	+12.5
	RH (%)	84	100	95	98	100	---	---	95	100	100	100	---	100	---

Table 8. Temperature and Computed Height Data (cont'd)

PRESSURE LEVEL		NCAR 4176	NCAR 4121	NCAR 4183	NCAR 4214	NCAR 4039	NCAR 4209	T-13 #4	RAOB	RAOB + T-13 MEAN	RAOB + T-13 STD DEV	NCAR MEAN	NCAR STD DEV
500 mb	HGT (m)	—	—	—	—	—	—						
	TEMP (°C)	—	—	—	—	—	—	-15.8	-15.1				
	RH (%)	—	—	—	—	—	—	54	39				
700 mb	HGT (m)	3102	3122	3110	3084	3092	3100	3114	3118	3120.0	3.7	3098.5	19.7
	TEMP (°C)	+1.3	+2.2	+1.7	+1.2	+1.5	+1.4	+1.8	+1.3	1.32	.65	2.08	1.37
	RH (%)	48	47	42	52	53	40	42	38				
850 mb	HGT (m)	1510	1529	1516	1496	1499	1508	1523	1527	1529.0	5.5	1509.4	24.0
	TEMP (°C)	+9.9	+9.7	+10.4	+9.1	+10.4	+10.8	+10.3	+10.3	9.58	0.97	9.79	1.40
	RH (%)	80	79	60	100	83	38	47	65				
1000 mb	HGT (m)	151	201	156	138	138	149	164	168	169.0	5.3	150.0	35.1
	TEMP (°C)	+11.8	+4.5	+12.0	+12.4	+12.2	+11.8	+12.7	+13.0	12.5	0.41	11.71	2.5
	RH (%)	100	88	100	93	92	100	92	72				
SURFACE	SLP (mb)	1018	1024	1019	1017	1017	1018	1019	1020	1020.0	0.9	1018.5	4.3
	TEMP (°C)	+11.7	+4.4	+12.0	+11.6	+12.3	+11.5	+12.7	+11.7	12.4	0.48	11.80	2.54
	RH (%)	100	88	100	100	93	100	94	72				

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Recommendations

a. Calibration reliability should be checked. Recalibration or "baselining" on the aircraft should not be required of an operational sonde.

b. The sonde should be environmentally tested for heat, cold, moisture, and vibration. The differences in sonde performance during wind tunnel testing, which was good, and flight testing cannot be explained without additional information.

c. Improve the pressure data for accuracy and repeatability. These qualities were not demonstrated during the flight test.

d. Validate temperature performance. Temperature measurements were for the majority good. Errors at the higher altitudes were due to pressure measurement errors.

e. Validate humidity performance.

f. Consider a design change to include reference oscillator signals which will provide frequency compensation for variations caused by cooling effects or reduced power supply voltage. Compensations for systematic measurement errors may include compensation for measurement lag caused by transducer response times.

BIBLIOGRAPHY

Hiers, R. S. and Carver, D. B.: "Meteorological Tunnel Tests of the NCAR Wind-Finding Dropsonde," AEDC-DR-75-31, Arnold Engineering Development Center, Arnold AFS, TN., April 1, 1975: Vol. I, pp. 1-370; Vol. II, pp. 371-797.

Morrissey, James F. and Weiss, Bernard D.: "Dropsonde Wind Measurements Using Omega/Loran Tracking," AFCRL-TR-0096, Instrumentation Papers No. 228, 19 February 1975, 32 p. (AD-A009634)

Govind, P. K.: "Performance Characteristics of the NCAR Dropsonde: Cape Kennedy Experiments," Test Report, Research Systems Facility, NCAR, Boulder, CO., October 1973, 31 p.

Atmospheric Technology (published for the NCAR Facilities Laboratory), Ronald Cox, Editor, National Center for Atmospheric Research, No. 2, June 1973.

Appendix A

EXAMPLES OF TEST DATA

f = frequency

f_a = frequency corresponding to p_a

f_B = frequency value for "200" division at bottom of strip chart

f_h = frequency height

f_ℓ = lower frequency

f_T = frequency value for "0" division at top of strip chart

f_1 = calculated print frequency at top of strip chart

f_2 = calculated print frequency at bottom of strip chart

p = pressure

p_a = mandatory pressure level

p_h = pressure height

p_ℓ = lower pressure

STRIP CHART CALIBRATION

#5620

	PRESSURE		TEMPERATURE		TEMPERATURE		HUMIDITY	
f_2	45,599	(Bottom)	9763.5	(Bottom)	97,635	(Bottom)	67,028	(Bottom)
f_1	32,445	(Top)	1005.9	(Top)	10,059	(Top)	11,499	(Top)
$f_2 - f_1$	13,154		8757.6		87,576		55,529	
# Div	185		188.7		188.7		181	
Hz/Div	71.10		46.41		464.1		306.79	

f_T:

PRESSURE: $32{,}445 - 71.10 \times 9 = 32{,}445 - 639.92 = 31{,}805.08 \text{ Hz}$

TEMPERATURE: $1005.9 - 46.41 \times 8 = 1005.9 - 371.28 = 634.62 \text{ Hz}$

TEMPERATURE: $10{,}059 - 464.1 \times 8 = 10{,}059 - 3712.8 = 6346.19 \text{ Hz}$

HUMIDITY: $11{,}499 - 306.79 \times 8 = 11{,}499 - 2454.32 = 9044.68 \text{ Hz}$

f_B:

PRESSURE: $45{,}599 + 71.10 \times 6 = 45{,}599 + 426.6 = 46{,}025.6 \text{ Hz}$

TEMPERATURE: $9763.5 + 46.41 \times 3.3 = 9763.5 + 153.15 = 9916.65 \text{ Hz}$

TEMPERATURE: $97{,}635 + 464.1 \times 3.3 = 97{,}635 + 1531.5 = 99{,}166.53 \text{ Hz}$

HUMIDITY: $67{,}028 + 306.79 \times 11 = 67{,}028 + 3374.69 = 70{,}402.69 \text{ Hz}$

#5584

	PRESSURE		TEMPERATURE		TEMPERATURE		HUMIDITY	
f_2	49,426	(Bottom)	9972.2	(Bottom)	99,722	(Bottom)	67,472	(Bottom)
f_1	32,051	(Top)	1055.8	(Top)	10,558	(Top)	11,496	(Top)
$f_2 - f_1$	17,375		8916.4		89,164		55,976	
# Div	201		201		201		181.5	
Hz/Div	86.44		44.36		443.6		308.41	

f_T:

PRESSURE: $32{,}051 - 86.44 \times (-2) = 32{,}051 + 172.88 = 32{,}223.88 \text{ Hz}$

TEMPERATURE: $1055.8 - 44.36 \times (-2) = 1055.8 + 88.72 = 1144.52 \text{ Hz}$

TEMPERATURE: $10{,}558 - 443.6 \times (-2) = 10{,}558 + 887.2 = 11{,}445.2 \text{ Hz}$

HUMIDITY: $11{,}496 - 181.5 \times 6 = 11{,}496 - 1089 = 10{,}407 \text{ Hz}$

f_B:

PRESSURE: $49{,}426 + 86.44 \times 1 = 49{,}426 + 86.44 = 49{,}512.44 \text{ Hz}$

TEMPERATURE: $9972.2 + 44.36 \times 1 = 9972.2 + 44.36 = 10{,}016.56 \text{ Hz}$

TEMPERATURE: $99{,}722 + 443.6 \times 1 = 99{,}722 + 443.6 = 100{,}165.6 \text{ Hz}$

HUMIDITY: $67{,}472 + 308.41 \times 12.5 = 67{,}472 + 3855.13 = 71{,}327.13 \text{ Hz}$

f_2 = CAL PRINT FREQ AT BOTTOM OF STRIP CHART.

f_1 = CAL PRINT FREQ AT TOP OF STRIP CHART.

f_T = FREQ VALUE FOR "0" DIVISION AT TOP OF STRIP CHART

f_B = FREQ VALUE FOR "200" DIVISION AT BOTTOM OF STRIP CHART.

TABULATED INTERPOLATION DATA

		500 MB	700 MB	850 MB	1000 MB
#5620	p	44,589.95	40,547.75	37,401.0	32,888.0
	$p_h =$	529.11	718.29	860.96	1,002.95
	$p_\ell =$	481.90	671.09	813.48	955.35
	$f_h =$	45,621.0	41,558.25	38,471.25	35,132.5
	$f_a =$	45,225.63	40,939.32	37,648.05	33,965.03
#5584	$f_\ell =$	47,960.0	43,212.25	39,043.0	33,963.5
	$p_h =$	529.03	717.40	860.46	1,001.88
	$p_\ell =$	481.83	671.49	812.57	954.85
	$f_h =$	49,081.0	44,426.75	40,522.5	35,757.25
	$f_a =$	48,649.46	43,672.54	39,366.15	34,035.2
#5613	$f_\ell =$	45,135.5	41,350.5	38,332.25	35,440.25
	$p_h =$	530.57	717.61	861.94	1,002.23
	$p_\ell =$	482.30	671.83	813.48	955.42
	$f_h =$	46,128.0	42,284.0	39,367.25	36,413.0
	$f_a =$	45,764.06	41,709.59	38,587.26	35,486.59

#5620

$$f_a = f_\ell + \left(\frac{p_h - p_a}{p_h - p_\ell}\right)(f_h - f_\ell)$$

$$f_{500} = 44,589.75 + \left(\frac{529.11 - 500}{529.11 - 481.90}\right)(45,621.0 - 44,589.75)$$

$$= 44,589.75 + \left(\frac{29.11}{47.21}\right)(1031.25)$$

$$= 44,589.75 + (0.617)(1031.25)$$

$$f_{500} = 44,589.75 + 635.88 = 45,225.63 \text{ Hz}$$

$$f_{700} = 40,547.75 + \left(\frac{718.29 - 700}{718.29 - 671.09}\right)(41,558.25 - 40,547.75)$$

$$= 40,547.75 + \left(\frac{18.29}{47.20}\right)(1010.50)$$

$$= 40,547.75 + (0.3875)(1010.50)$$

$$f_{700} = 40,547.75 + 391.57 = 40,939.32 \text{ Hz}$$

<u>#5620</u>
(Cont'd)

$f_{850} = 37{,}401.0 + \left(\dfrac{860.96 - 850}{860.96 - 813.48}\right)(38{,}471.25 - 37{,}401.0)$

$= 37{,}401.0 + \left(\dfrac{10.96}{47.48}\right)(1070.25)$

$= 37{,}401.0 + (0.231)(1070.25)$

$f_{850} = 37{,}401.0 + 247.05 = 37{,}648.05 \text{ Hz}$

$f_{1000} = 33{,}888.0 + \left(\dfrac{1002.95 - 1000}{1002.95 - 955.35}\right)(35{,}132.5 - 33{,}888.0)$

$= 33{,}888.0 + \left(\dfrac{2.95}{47.60}\right)(1244.50)$

$= 33{,}888.0 + (0.0619)(1244.50)$

$f_{1000} = 33{,}888.0 + 77.03 = 33{,}965.03 \text{ Hz}$

<u>#5584</u>

$f_a = f_\ell + \left(\dfrac{p_h - p_a}{p_h - p_\ell}\right)(f_h - f_\ell)$

$f_{500} = 47{,}960.0 + \left(\dfrac{529.03 - 500}{529.03 - 481.83}\right)(49{,}081 - 47{,}960)$

$= 47{,}960.0 + \left(\dfrac{29.03}{47.20}\right)(1121.0)$

$= 47{,}960.0 + (0.615)(1121.0)$

$f_{500} = 47{,}960.0 + 689.46 = 48{,}649.46 \text{ Hz}$

$f_{700} = 43{,}212.25 + \left(\dfrac{717.4 - 700}{717.4 - 671.49}\right)(44{,}426.75 - 43{,}212.25)$

$= 43{,}212.25 + \left(\dfrac{17.4}{45.91}\right)(1214.5)$

$= 43{,}212.25 + (0.379)(1214.5)$

$f_{700} = 43{,}212.25 + 460.29 = 43{,}672.54 \text{ Hz}$

$f_{850} = 39{,}043.0 + \left(\dfrac{860.46 - 850}{860.46 - 812.57}\right)(40{,}522.5 - 39{,}043.0)$

$= 39{,}043.0 + \left(\dfrac{10.46}{47.89}\right)(1479.5)$

$= 39{,}043.0 + (0.218)(1479.5)$

$f_{850} = 39{,}043.0 + 323.15 = 39{,}366.15 \text{ Hz}$

$f_{1000} = 33{,}963.5 + \left(\dfrac{1001.88 - 1000}{1001.88 - 954.85}\right)(35{,}757.25 - 33{,}963.5)$

$= 33{,}963.5 + \left(\dfrac{1.88}{47.03}\right)(1793.75)$

$= 33{,}963.5 + (0.0399)(1793.75)$

$f_{1000} = 33{,}963.5 + 71.7 = 34{,}035.2 \text{ Hz}$

#5613 $\qquad f_a = f_\ell + \left(\dfrac{p_h - p_a}{p_h - p_\ell}\right)(f_h - f_\ell)$

$$f_{500} = 45{,}135.5 + \left(\frac{530.57 - 500}{530.57 - 482.3}\right)(46{,}128.0 - 45{,}135.5)$$

$$= 45{,}135.5 + \left(\frac{30.57}{48.27}\right)(992.5)$$

$$= 45{,}135.5 + (0.633)(992.5)$$

$$f_{500} = 45{,}135.5 + 628.56 = 45{,}764.06 \text{ Hz}$$

$$f_{700} = 41{,}350.5 + \left(\frac{717.61 - 700}{717.61 - 671.83}\right)(42{,}284.0 - 41{,}350.5)$$

$$= 41{,}350.5 + \left(\frac{17.61}{45.78}\right)(933.5)$$

$$= 41{,}350.5 + (0.385)(933.5)$$

$$f_{700} = 41{,}350.5 + 359.09 = 41{,}709.59 \text{ Hz}$$

$$f_{850} = 38{,}332.25 + \left(\frac{861.94 - 850}{861.94 - 813.48}\right)(39{,}367.25 - 38{,}332.25)$$

$$= 38{,}332.25 + \left(\frac{11.94}{48.46}\right)(1035.0)$$

$$= 38{,}332.25 + (0.246)(1035)$$

$$f_{850} = 38{,}332.25 + 255.01 = 38.587.26 \text{ Hz}$$

$$f_{1000} = 35{,}440.25 + \left(\frac{1002.23 - 1000}{1002.23 - 955.42}\right)(36{,}413.0 - 35{,}440.25)$$

$$= 35{,}440.25 + \left(\frac{2.23}{46.81}\right)(972.75)$$

$$= 35{,}440.25 + (0.048)(972.75)$$

$$f_{1000} = 35{,}440.25 + 46.34 = 35{,}486.59 \text{ Hz}$$

Appendix B

TEST RESOURCE MANAGEMENT

Test Costs:

1. Contractor Support:

 a. Four man-weeks consultant services $ 2,430.00

 b. Instrumentation Equipment rental $ 1,500.00

 c. Twenty dropsondes $ 6,000.00

            Subtotal $ 9,930.00

2. Flight Test Support:

 a. WC-130H aircraft (19 hours at $811.00/hr)* $15,409.00

 b. Test Range support   (No Direct Cost)

 c. AWS test personnel (TDY) $ 151.00

            Subtotal $15,560.00

               $ 9,930.00
               $15,560.00

         Total Test Cost $25,490.00

 * WC-130H Flying Hour Cost Factors (FY 1975 Base Year)

    Fuel $304.00
    Depot Maintenance $129.00
    Base Maintenance
     Material $ 60.00
     Labor $273.00
    Spares $ 45.00

       Total $811.00

NOTE: A total of 19 hours were flown on three different flights
    to support the test. Two flights were terminated because
    of receiver/processor malfunctions. All test sondes were
    dropped on the third mission which took 8 hours flying
    time.

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